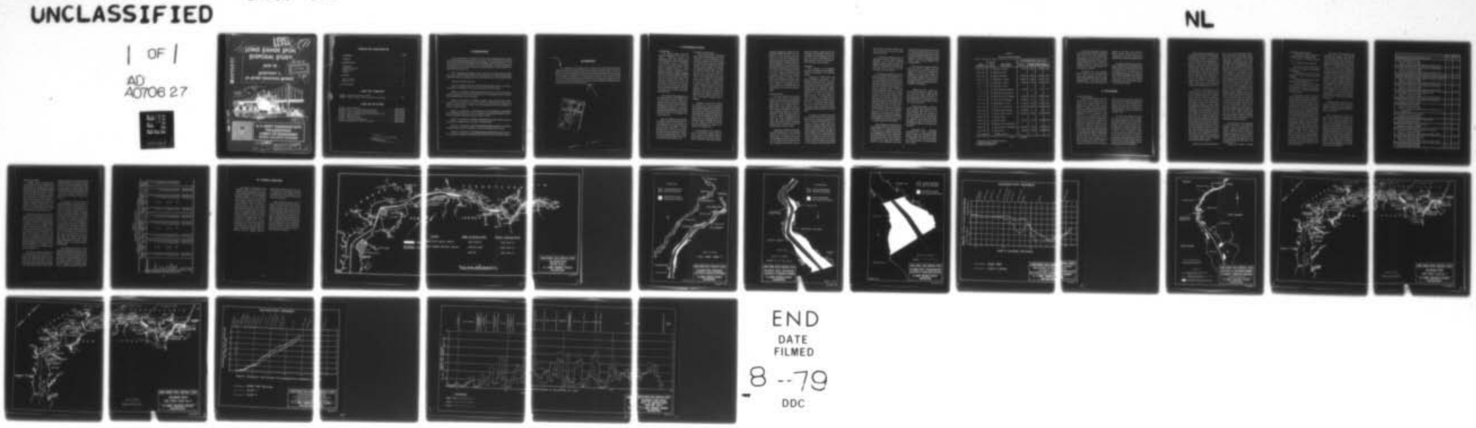
AD-A070 627 ARMY ENGINEER DISTRICT PHILADELPHIA PA F/G 8/8
LONG RANGE SPOIL DISPOSAL STUDY. PART VI. SUBSTUDY 5. IN-RIVER --ETC(U)
JUN 69

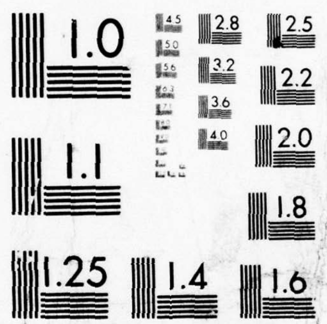
UNCLASSIFIED NL

| OF |

AD
A070627



END
DATE
FILMED
8 --79
DDC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

LEVEL III

A060 626

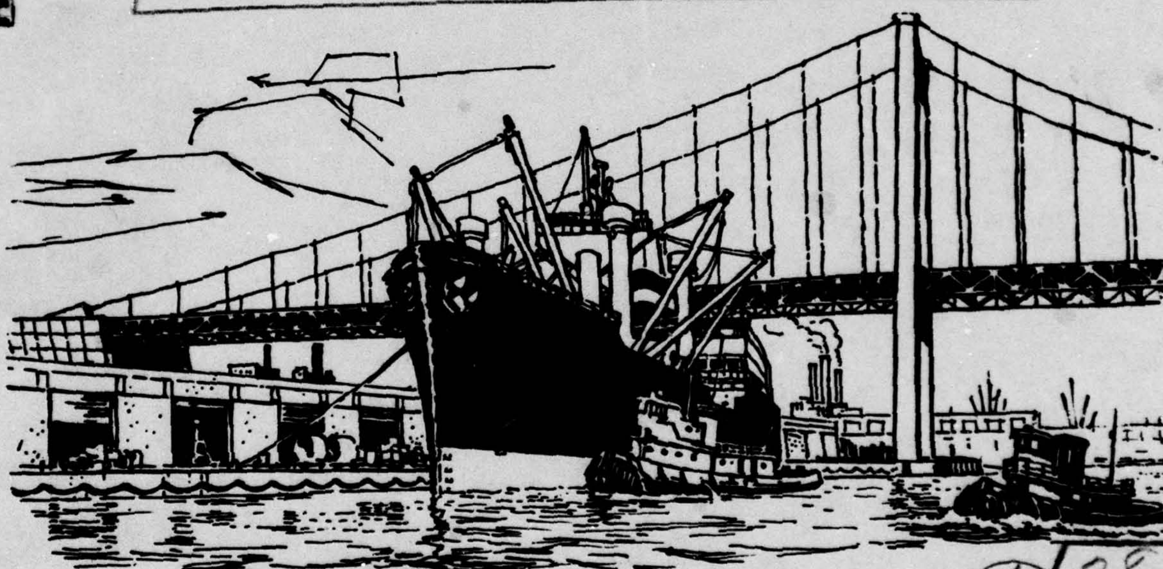
AD A070627

(6) # LONG RANGE SPOIL DISPOSAL STUDY.

D D C
RECEIVED
JUN 29 1979
C

PART VI.

SUBSTUDY 5.
IN-RIVER TRAINING WORKS.



(12) 38p.

DDC FILE COPY

U.S. ARMY ENGINEER DIST.
PHILADELPHIA
CORPS OF ENGINEERS
NORTH ATLANTIC DIVISION

(11) JUN[redacted]69

410 358

mt

TABLE OF CONTENTS

	Page
FOREWORD	i
SUMMARY	ii
I. INTRODUCTION	1
Background	1
Purpose of this Study	1
Scope of Study	2
Problem	2
II. STUDIES	5
Plans Considered	5
Results of Tests	9
III. CONCLUSIONS	11

LIST OF TABLES

TABLE 1 - Channel and Anchorage Shoaling 4
TABLE 2 - Effects of Plans 7 and 11 on Accumulative Shoaling 10

LIST OF PLATES

PLATE 1 - Major Shoal Areas . . . . . Back of book
PLATE 2a, 2b, 2c - Location of Shoreline Revisions . . . . . Back of book
PLATE 3 - Velocity Data; Bottom Flow Predominance . . . . . Back of book
PLATE 4 - Channel and Shoreline Revisions 50' Channel Tests . . . . . Back of book
PLATE 5 - Dike Study, Plan 7. . . . . Back of book
PLATE 6 - Dike Study, Plan 11. . . . . Back of book
PLATE 7 - Accumulated Shoaling Data . . . . . Back of book
PLATE 8 - Shoaling Rates - Model Test Results. . . . . Back of book

FOREWORD

This study and report was completed as one of the six Sub-Studies which comprise the overall Long Range Disposal Study in the Delaware. The overall study was conceived and initiated by the then Philadelphia District Engineer, Colonel W.W. Watkin, Jr., who had been directed to such an effort by the Chief of Engineers. The Project Manager for this Sub-Study was Mr. Joseph F. Phillips with guidance from Mr. Lloyd A. Duscha, P.E. and Mr. Lewis Caccese, P.E.

The "Long Range Spoil Disposal Study" consists of seven parts which are listed below. Part I, which is "General Data on the Delaware River," contains detailed background data which is pertinent to this report. This report is Part VI of the overall study.

The study is divided as follows:

PART I - GENERAL DATA ON THE DELAWARE RIVER furnishes the information and data on the Delaware River which is pertinent to the entire study.

PART II - SUB-STUDY 1, SHORT RANGE SOLUTION evaluates the remaining disposal area capacity in terms of its remaining life, and to recommend any further desirable and acceptable disposal area developments.

PART III - SUB-STUDY 2, NATURE, SOURCE, AND CAUSE OF THE SHOAL develops, in depth, the basic data as to the nature of the Delaware River shoals, their sources, and their causes. It is hoped that this knowledge may reveal new concepts for the better control of shoals.

PART IV - SUB-STUDY 3, DEVELOPMENT OF NEW DREDGING EQUIPMENT AND TECHNIQUE identifies the best in dredging plant and dredging technique for Delaware River dredging maintenance tasks now and in the future.

PART V - SUB-STUDY 4, PUMPING THROUGH LONG LINES examines the merits of transporting dredging materials many miles through pipelines.

PART VI - SUB-STUDY 5, IN-RIVER TRAINING WORKS determines the potential of training works for control of shoaling. It involves considerable model testing.

PART VII - SUB-STUDY 6, DELAWARE RIVER ANCHORAGES considers the effect of man-made anchorage on shoaling problems and the merits of alternate solutions.

SUMMARY

It is apparent that the changes in river sections that would result from extreme canalizing of the estuary would not induce the necessary downstream shift of the shoaling due to the effect of salinity density currents. Extensive training works to reduce the flow area also were ineffective in moving the several shoaling areas downstream enough to be of benefit in reducing the cost of maintenance. Since the shoals cannot be moved out of the present high shoaling areas with the aid of training works regardless of cost, it will be necessary to develop improved and more efficient methods of dredging and disposing of material from the existing system.

I. INTRODUCTION

BACKGROUND

The Delaware River, and particularly the Philadelphia Port Area, constitutes a major port complex. Over 100,000,000 tons of waterborne commerce move through the Port of Philadelphia each year. This commerce relies in large part on the man made 40-foot channel which is constantly subjected to regular shoaling. Therefore, maintenance of the 40-foot depth requires constant dredging. With the result that 7,000,000 to 8,000,000 cubic yards of shoal material are dredged from the Delaware River channel and anchorages and placed ashore each and every year. A characteristic of this dredging is that, for the most part, shoaling, and the subsequent dredging, takes place in repetitive locations and at reasonably predictable rates.

The most significant shoaling areas are: Marcus Hook, Pa., Philadelphia, Pa. and New Castle, Delaware. These areas represent the majority of the dredging requirements necessary to maintain the Port of Philadelphia. From this, it is apparent that any better approaches to the dredging and spoil disposal problems in these areas will have relevance to the dredging work in the entire river.

Since the shoaling occurs primarily at specific locations, disposal areas for the dredged spoil in these vicinities are of key importance. The supply of disposal areas in these critical areas is severely limited because of past use of the most desirable areas and the physical development of the remaining areas. Plate 1 shows the most significant shoaling areas of the river and the related disposal areas.

PURPOSE OF THIS STUDY

One of the objectives of the Long Range Spoil Disposal Study for the Delaware River is the determination as to whether any modification of the shoreline by training works or additional training structures could be effective in appreciably reducing the shoaling of the navigation channels and anchorages, or in shifting areas to locations from which the material could be disposed of more economically. All feasible improvement plans were to be considered and evaluated initially without regard to economic costs or relation to existing or potential developments along the river. In the extreme instance, partial canalization and major reduction in width of river, could be envisioned. It was desired to consider any plan which would eliminate or reduce to a major extent the shoaling which now occurs in the navigation channels and anchorages.

Although a utopian goal of flushing all sediment to the ocean was sought, it was recognized that any plan which would encourage the shoaling to concentrate in areas downstream of Philadelphia, Marcus Hook, and other intensely developed areas from which the dredging and proper disposal could be accomplished more economically would be of benefit. This would, of course, require coordination with the plans for development of onshore or inclosed river disposal areas.

The determination of the effectiveness of any proposed training works can best be tested in the hydraulic model of the Delaware Estuary at the Corps of Engineers Waterways Experiment Station,

Vicksburg, Mississippi, (Referred to subsequently as WES). This model was completed in 1947 and has been used intermittently ever since for testing many different proposals involving training dikes, channel alignments, sediment traps, dispersion of pollution, river entrance jetties, and flow regulation plus others. The model has also been utilized by private interests for a variety of tests. The model, built to a scale of 1:1000 vertically and 1:100 horizontally, includes the entire Estuary, Capes to Trenton (a distance of 132 miles) and the tidal portions of most tributaries. The results of a number of previous hydraulic and shoaling tests of various plans were considered when developing plans to be tested in the present study.

SCOPE OF STUDY

The study included review of the results of tests made in the Delaware Estuary Model for an enlarged navigation channel, and of the tests of considered improvements in the Schuylkill River - Marcus Hook reach. Analysis was also made of tests accomplished at the Waterways Experiment Station for the Corps Committee on Tidal Hydraulics which involved an extreme streamlining of the Estuary for study of flushing characteristics. This study investigated the hydraulic and shoaling effects of proposed training works in specific reaches from Pettys Island to Artificial Island.

Updating and summarizing the dredging and shoaling data of the navigation channels was included as part of this study. Effects on shoaling trends of the private dredging for maintenance of slips, etc., and sand and gravel operations were also considered. The locations to be considered for potential training works were coordinated with possible sites for the development of in-river disposal areas for future use, and the effectiveness of enlarging specific areas of the estuary to act as silt traps was investigated.

PROBLEM

The shoaling of the navigation channels and anchorages of the Delaware Estuary is attributed to the following sources:

1. *Erosion of Upland Areas and Beds and Banks of Tributaries* - The sediment produced thereby is carried to the Estuary by fluvial flow, particularly during high flow periods. Based on data secured from the suspended sediment sampling station at Trenton, New Jersey, operated for 20 years by the U.S. Geological Survey, and other stations of shorter duration, it is estimated that the total contribution to the estuary from upland sources is about 2.2 million tons per year. This is equivalent to about 4.8 million cubic yards of material as dredged. This total includes an assumed bed load contribution equal to 10% of the suspended load.

2. *Changes in the Bed of the Estuary* - Outside the limits of the navigation channels and anchorages changes occur due to natural and man-made causes. A change in velocity regimen could result in scour or shoaling, modification of the effective shoreline by structures could influence the velocity pattern, and sand and gravel dredging could induce changes as well as indicate scour. Analysis of available data indicates that the bed of the estuary (as defined above) from Trenton to New Castle has deepened at an annual rate of 2.6 million cubic yards, while from

New Castle to Artificial Island, there has been shoaling of about one million cubic yards a year.

3. Additional possible sources of shoaling are erosion of banks, dredging operations, sewer effluents, industrial effluents, natural organic processes, and inflow from the Atlantic Ocean. Quantities from these sources have not yet been evaluated to any useful degree.

The apparent shoaling rates for the navigation channels and anchorages have been developed based on repetitive surveys and dredging records obtained since 1955. Prior to this date older and different methods of dredging and disposal were in use and the data are not comparable to present conditions. Table 1 lists the estimated annual shoaling rates. It should be noted that the total annual average shoaling is approximately 9 million cubic yards for the navigation channels and anchorages. The rate of shoaling per unit length of channel in the Marcus Hook area is more than twice that in any other reach. The enlargement of the river area due to the Marcus Hook Anchorage is considered to be a major cause of this condition. Since this is also the reach of high industrial use with additional developments being planned, the disposal of maintenance dredging from this reach of the river is rapidly becoming a major problem.

The development of disposal areas by enclosing areas of the river with retaining dikes is a physical possibility, of course, but any substantial and economic development of this type would likely bring forth objections from conservationists and others. Such a plan is being envisioned for the upper end of Tinicum Island, but many objections from some industries and boating interests will have to be overcome before this plan can come to fruition. Enclosing large areas of the river also affects the tidal prism, causing changes in currents in the upstream areas which in turn can cause changes in the shoaling pattern.

Over the years a number of training works have been constructed along the Estuary for the purpose of improving the alignment of currents and reducing the shoaling rates along specific reaches of the navigation channels. The major works are described briefly in the following subparagraphs, moving geographically downstream from Philadelphia:

1. Mifflin Bar Dike - Along west shore, opposite Billingsport Range, original construction began in 1885 and the dike was raised in 1894 and 1916. The required maintenance of the navigation channel in this reach was materially decreased as a result of this work.

2. Chester Island Dike - Across secondary channel along New Jersey shore and connecting with upstream end of Chester Island. Dike was completed in 1915 and the effective flow section of the river was reduced and the main channel was deepened. Scour holes have since developed at either end of the dike, but the beneficial effects of the dike have continued.

3. Pennsville Dike - Extending downstream from the New Jersey shore along the upper end of Deepwater Point Range, the dike was constructed in 1944. In combination with Pea Patch Island Dike, local benefits of reduced shoaling were realized.

TABLE 1

Channel and Anchorage Shoaling

Reach Channel Stas.	Miles from Mouth*	Channel Ranges and Anchorages.	Annual Shoaling Rates, Cubic Yards			
			Total Av. for Reach	Rate per 1000 ft. of Chan.		
				Average	Median	Maximum
-153 to -150	131	Trenton - Cochran	57,000	19,000	17,000	33,000
-150 to -148	130	Cochran - Biles	–	–	–	–
-148 to -132	128	Biles - Whitehill	204,000	12,800	13,000	33,000
-132 to - 96	123	Whitehill - Landreth	428,000	11,900	11,000	31,000
- 96 to - 63	116	Landreth - Beverley	501,000	15,200	13,000	42,000
- 63 to 0	108	Beverley - Harbor	–	–	–	–
0 to + 4	103	Port Richmond Anchorage	95,000	NA	NA	NA
+ 4 to + 55	98	Philadelphia Harbor Rges.	–	–	–	–
+ 55 to + 77	88	W. Horseshoe - Billingsport	706,000	32,100	25,000	81,000
+ 61 to + 72	92	Mantua Creek Anchorage	430,000	NA	NA	NA
+ 77 to +113	83	Billingsport - Chester	413,000	11,500	10,500	36,000
+113 to +131	79	Chester - Marcus Hook	2,142,000	119,000	121,000	192,000
+118 to +131	81	Marcus Hook Anchorage	400,000	NA	NA	NA
+131 to +164	74	Marcus Hook - Bellevue	1,405,000	42,600	44,500	103,000
+164 to +167	71	Cherry Island	–	–	–	–
+167 to +175	70	Cherry Island	570,000	47,500	61,000	121,000
+175 to +188	68	Cherry Island - Deepwater P.	–	–	–	–
+188 to +221	63	Deepwater P. - Bulkhead Bar	1,022,000	31,000	31,000	100,000
+221 to +235	58	New Castle	792,000	56,600	57,000	178,000
+235 to Mouth		Baker, Liston, etc.	–	–	–	–
		Total	9,165,000			

*Miles shown are at mid-points of reaches.
–Signifies negligible shoaling
NA signifies not applicable

4. Pea Patch Island Dike - Extending upstream from Pea Patch Island along the west side of New Castle to Deepwater Point Ranges. It was constructed in 1932 and produced some local effects in shifting the shoaling. However, no reduction in shoaling along this reach of river was realized until the above described Pennsville Dike was completed.

5. Bulkhead Bar and Kilcohook Dikes - These are located along the New Jersey shore opposite the Pea Patch Island Dike. Bulkhead Bar Dike extending perpendicularly to the shore was constructed in 1892, and the Kilcohook Dike parallel to the shore was constructed during 1924-26. Together they form a constriction in the river and form the boundaries of the Kilcohook Disposal Area.

6. Reedy Island Dike and Artificial Island - The dike extends downstream from Reedy Island, and Artificial Island forms a constriction and is connected to the New Jersey shore. The construction of this combined improvement was completed about 1917 and resulted in some scouring of the main river section and reduced maintenance effort along the Baker Range of the navigation channel.

II. STUDIES

PLANS CONSIDERED

It can be theorized that if the shoaling material is to be transported by the currents to the Atlantic Ocean or to the deeper areas of Delaware Bay, the river should be reshaped to provide gradually increasing sections from the head of navigation toward Delaware Bay. Local enlargements such as anchorages, which tend to act as sediment traps, should therefore be excluded from consideration. Such a plan was tried in connection with flushing tests conducted at WES by other interests, in which the Delaware Estuary Model was utilized for such tests. The estuary was streamlined from Philadelphia to near Miah Maull Light with the widths increasing from about 2000' at Philadelphia to about 8000' in Delaware Bay. The shoreline revisions are shown on the 3 sheets of Plate 2. While no shoaling tests were accomplished, analysis of the resulting flow conditions reveal that there would be a net upstream flow along and near the bottom to a point just upstream of New Castle. Thus, there would be no possibility with this plan of inducing the shoaling material (which moves generally near the bottom) to advance seaward beyond New Castle.

As part of this flushing investigation, tests were also run with a considerably lesser modification of the shoreline, also shown on Plate 2. The results of the hydraulic tests with this plan also show a net upstream flow along the bottom for as far upstream as Pea Patch Island, which is about 5 miles downstream of New Castle. It appears that as the irregularities of the river cross-sections are reduced, the tendency for stratification of flow to develop is increased. The resulting density currents due to salinity produce the net upstream movement near the bottom.

These flushing tests brought out the relationship of upstream and downstream currents near the bottom at various locations along the estuary. A comparison of the data resulted in establishing what is known as a "null" point. This marks the location downstream of which the bottom currents have a net upstream movement and upstream of which the net movement near the bottom is toward the ocean. The shifting of this null point is indicative of how far downstream one could hope to transfer the shoaling material under the various plans tried or envisioned. Examples of the upstream and downstream velocity relationships are shown on Plate 3.

A previous investigation of the section of the river from Schuylkill River to Marcus Hook involving dikes, sediment traps, and disposal areas was reported on in Misc. Paper No. 2-887 of the Waterways Experiment Station. This report dated March 1967 is titled "Results of Hydraulic and Shoaling Studies in Marcus Hook Schuylkill Reach of Delaware River." This investigation was concerned with what improvements would be feasible to reduce the dredging costs in that heavy shoaling reach of the river. While the purposes of these tests did not include the development of plans for shifting the shoal downstream of this reach, there was no evidence that the enclosing of some water areas to provide for disposal of dredge spoil would have any major beneficial effect on shifting of the shoaling areas to any appreciable degree in the downstream direction. The plans tested included silt traps as well as diked areas and it was noted that the shoaling pattern could be shifted locally with only little benefit.

Model tests were also conducted as part of the "Channel Dimension Study," but a formal report on the results of these tests is not yet available. The channel improvement considered in this study would result in a 50' deep channel, generally 1000' wide from Philadelphia to the Sea. The plan envisioned that numerous disposal areas would have to be established to retain the large amount of new work dredging. It was assumed that few areas would be available, and that diked areas in the estuary would be required. The channel alignment and ultimate shoreline revisions as tested are shown on Plate 4. The results of the model tests indicated an overall shoaling index of 1.5 for the areas to be maintained, which means that the shoaling rate with the modified channel alignment and revised shoreline would be 50 percent higher than with existing conditions. This increase is due to a greater tendency for retention of material in the proposed deeper and wider navigation channel. The reductions in river cross-sections caused by the diked areas along some reaches did reduce the shoaling in specific ranges, but the effect was localized. Again, there was no evidence that these extensive diked areas would be effective in shifting the shoaling pattern downstream to any significant and beneficial degree.

In connection with the Long Range Disposal Area Studies, it was decided to consider a plan of training works that would be extensive and that could be expected to shift the location of intensive shoaling downstream to near Artificial Island if possible. The location and extent of these training works were to be considered without the imposition of any constraints due to:

1. Effect on or relation to existing

developments along the shore

2. Existing or future channel and anchorage locations and dimensions

3. Location of proposed disposal areas

4. Probable cost of construction

The layout of these proposed training works was designed to accomplish the following:

1. Allow moderate increase in tidal currents in areas of present intensive shoaling;

2. Align the tidal currents to prevent deposition in undesirable areas;

3. Provide openings at the downstream end of the major dikes to prevent any appreciable changes in the general tide levels and to prevent any reduction in the tidal prism.

In consultation with the staff at the Waterways Experiment Station a number of training works, which appeared to have a potential beneficial effect, were located on maps of the Estuary. Eighteen items, including dikes, artificial fills, disposal areas, and silt traps, were considered, and grouped in various combinations into 16 plans for proposed testing in the model to determine their hydraulic effects. Prior to actual testing in the model, further discussions were held and it was decided that the first complete testing would be accomplished with the elements of Plan 7 installed in the model, which consisted of 15 elements between Pettys Island and Artificial Island. These elements are located on Plate 5. The elements of Plans 8, 9 and 10 were minor modifications and some deletions of those in Plan 7. Only partial model tests were conducted with these plans installed, and visual effects were noted during the tests of Plans 8, 9 and 10.

The results of the Hydraulic and shoaling tests of Plan 7 were reviewed and discussed with WES staff. The effects on currents were also viewed in the model by engineers from the District. Modifications and deletions of some elements were considered desirable. Additional tests were then accomplished with the elements of Plan 11 installed in the model. See Plate 6 for layout. Details of Plans tested and results obtained are discussed in later paragraphs. The major difference in Plan 11 when compared to Plan 7 is that the upstream ends of the training dikes were lowered to about mean low water to allow more upstream flow during flood current. The range of tide above Wilmington was reduced from present values as a result of the Plan 7 training dikes, and the contours along the dikes of Plan 11 would provide for greater flood flows.

Shoaling tests were performed in the model for only Plan 7 and 11, and the elements of these plans are described in detail as follows and shown on Plates 5 and 6, respectively.

Other modifications of these elements were installed in the model after Plan 7 tests and partial hydraulic tests were run. The analysis of these data resulted in the development of Plan 11 to represent the most likely plan of accomplishing the desired results. As previously indicated no estimates of costs or probable economic justification were evaluated for these plans as it was desired to determine whether any system of training dikes regardless of cost could cause the shoaling areas to shift downstream to desirable locations without detriment to the normal tide and velocity conditions.

	Plan 7	Plan 11
Enlargement of Pettys Island for Disposal Area	X	X
Dike at Philadelphia Navy Yard		
7850 feet in length above MHW	X	
5000 feet in length above MHW, 2850 feet in length at MLW		X
Dike from New Jersey shore, opposite mouth of Schuylkill River		
17150 feet in length above MHW	X	
13000 feet in length above MHW, 4150 feet in length at MLW		X
Tinicum Island Disposal Area with stream-lined channel thru Island	X	X
Dike encompassing Chester-Monds Island and extending downstream		
16000 feet in length above MHW	X	
12000 feet in length above MHW, 1200 feet in length at MLW		X
Dike from New Jersey shore, opposite Marcus Hook Anchorage		
21650 feet in length above MHW	X	
20500 feet in length above MHW, 2650 feet in length at MLW		X
Dike extending south from mouth of Oldmans Creek		
31500 feet in length above MHW	X	
30150 feet in length above MHW, 4350 feet in length at MLW		X
Dike along Delaware shore, under Delaware Memorial Bridge		
18500 feet in length above MHW	X	
Dike including Pennsville Dike		
15500 feet in length above MHW	X	
8400 feet in length above MHW, 4100 feet in length upper end existing dike		X
Dike including Pea Patch Island Dike		
11500 feet in length above MHW	X	
Dike extending from south end of Pea Patch Island		
4500 feet in length above MHW	X	
Dike south from Finns Pt. along Salem Cove		
19000 feet in length above MHW	X	
Dike connecting Reedy Island with Reedy Pt. South Jetty		
15600 feet in length above MHW	X	
11000 feet in length above MHW, 2750 feet in length at MLW		X
Dike extending south from Elsinboro Pt.		
10000 feet in length above MHW	X	
7250 feet in length above MHW, 2750 feet in length at MLW		X
Dike including Reedy Island Dike		
17000 feet in length above MHW	X	X

RESULTS OF TESTS

Analysis of the data secured from these recent model tests indicated that with the Plan 7 training works in place the range of tide was increased one-half foot for the reach from Ship John to New Castle, and a decrease of 0.5 to 1 foot for the reach upstream of Edgemoor. Similar data for the Plan 11 system of dikes indicate that the range of tide would be generally in agreement with the base test values or existing conditions. This is no doubt due to the lowering of the upper section of the dikes which allowed more flow, particularly during flood current.

The location and extent of the training dikes, of course, influence the currents in localized areas. The maximum velocities at the center of the channel generally show an increase with Plan 7 installed when compared with base test conditions. With Plan 11, these channel velocities are generally less than with Plan 7. However, at the upper end of Liston Range and along Marcus Hook Range the velocities with Plan 11 are somewhat greater than the base test. The maximum velocity during the tidal cycle was about 4 feet per second and occurred along the upper end of Liston Range with Plan 11, as compared to 3½ feet per second at several locations under base test conditions.

The effects of salinity conditions in the Estuary were noted with the Plan 7 system of training dikes installed in the model. The results show that in the general area of the Pa-Del State Line the equivalent salinity concentration at high water slack would be about 5 miles further upstream with Plan 7 than under existing conditions. This is a situation to be anticipated as a result of the decrease in range of tide. Since the normal range of tide was substantially recovered with the Plan 11 dikes it can be expected that the salinity pattern with Plan 11 would also be much closer to that under existing conditions.

The testing to show the effect on shoaling quantities and patterns was detailed to the extent that material was retrieved from units of channel 5000 feet in length. The results are shown on Table 2 and the accumulated values of shoaling quantities are plotted on Plate 7. It should be noted that the quantity retrieved from the channel and anchorages during the test of Plans 7 and 11 was approximately 10% less than for the base test. Therefore, a comparison of distribution of shoaling should take this into account. There is evidence of an upstream shift of the shoaling in Tinicum Range and a downstream shift from the Marcus Hook area for the dike plans. The results of the Plan 11 tests show that material that shoaled Marcus Hook Range in the base test was probably shifted to the Bellevue-Cherry Island Ranges.

The shoaling with the Plan 7 dikes indicated more intensive shoaling in scattered areas probably due to the more severe changes in the flow characteristics along the estuary. The block diagram, Plate 8, illustrates the channel shoaling by the unit reaches. There is no evidence of appreciable shifting of the intensive shoaling in a significant downstream direction.

TABLE 2

DELAWARE RIVER MODEL DIKE STUDY

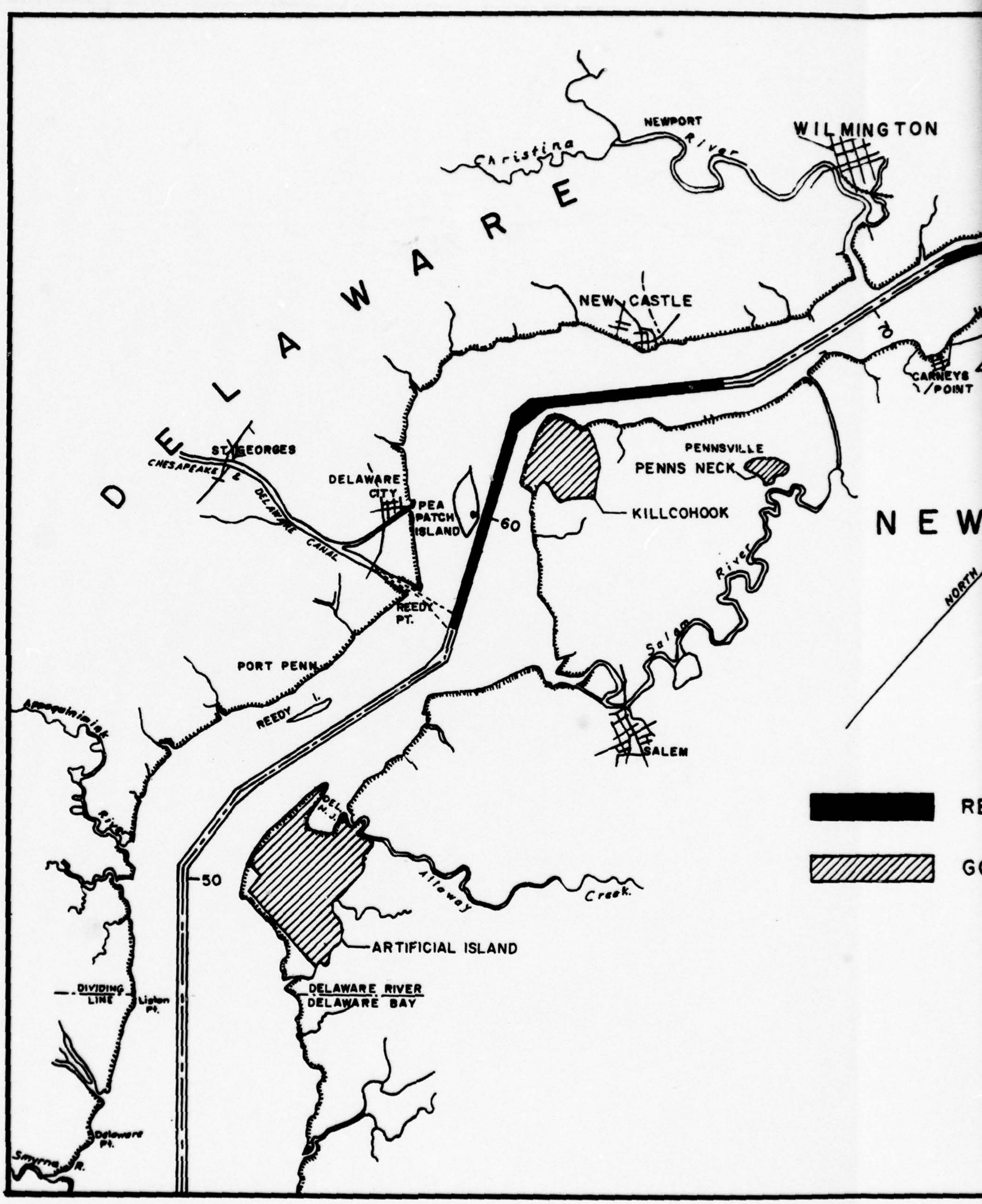
EFFECTS OF PLANS 7 AND 11 ON ACCUMULATIVE TOTAL SHOALING

AREA	BASE TEST			PLAN 7 DIKES				PLAN 11 DIKES				Diff. in Totals Plan 11 - Plan 7
NAVIGATION RANGE	Channel Volume cu cm	Anchorage Volume cu cm	Accum. Total cu cm	Channel Volume cu cm	Anchorage Volume cu cm	Accum. Total cu cm	Difference cu cm	Channel Volume cu cm	Anchorage Volume cu cm	Accum. Total cu cm	Difference cu cm	
Delair	100		100	70		70	- 30	110		110	+ 10	+ 40
Draw	35		135	50		120	- 15	40		150	+ 15	+ 30
Fisher	30		165	40		160	- 5	30		180	+ 15	+ 20
Harbor	90		255	85		245	- 10	75		255	0	+ 10
Phila. Waterfront	1585	290	2,130	2190	255	2,690	+ 560	1615	195	2,065	- 65	- 625
Horseshoe	790		2,920	1175		3,865	+ 945	800		2,865	- 55	- 1000
Mifflin	2360	3870	9,150	1140	115	5,120	- 4030	3800	1490	8,155	- 995	+3035
Billingsport	460		9,610	1730		6,850	- 2760	475		8,630	- 980	+1780
Tinicum	2810		12,420	4570		11,420	- 1000	1755		10,385	- 2035	- 1035
Eddystone	145		12,565	500		11,920	- 645	285		10,670	- 1895	- 1250
Chester	845		13,410	1385		13,305	- 105	665		11,335	- 2075	- 1970
Marcus Hook	5595	5605	24,610	6300	2315	21,920	- 2690	3835	955	16,125	- 8485	- 5795
Bellevue	2820		27,430	3620		25,540	- 1890	5060		21,185	- 6245	- 4355
Cherry Island	3935	2090	33,455	4645	385	30,570	- 2885	4595	360	26,140	- 7315	- 4430
Deepwater Point	4825		38,280	3120		33,690	- 4590	6145		32,285	- 5995	- 1405
Bulkhead Bar	455		38,735	1465		35,155	- 3580	425		32,710	- 6025	- 2645
New Castle	5355		44,090	910		36,065	- 8025	5705		38,415	- 5675	+2350
Reedy Island	2585	1560	48,235	3230	300	39,595	- 8640	3915	300	42,630	- 5605	+3035
Baker	1215		49,450	4040		43,635	- 5815	1250		43,880	- 5570	+ 245
Liston:												
62-65	1010		50,460	1795		45,430	- 5030	350		44,230	- 6230	
66-68	4000		54,460	2785		48,215	- 6245	4670		48,900	- 5560	
69-71	2455		56,915	2920		51,135	- 5780	2930		51,830	- 5085	
72-74	3185		60,100	2430		53,565	- 6535	2650		54,480	- 5620	
75-77	3185		63,285	3335		56,900	- 6385	3870		58,350	- 4935	
78-80	3960		67,245	4155		61,055	- 6190	3820		62,170	- 5075	
81-83	1775		69,020	1520		62,575	- 6445	985		63,155	- 5865	

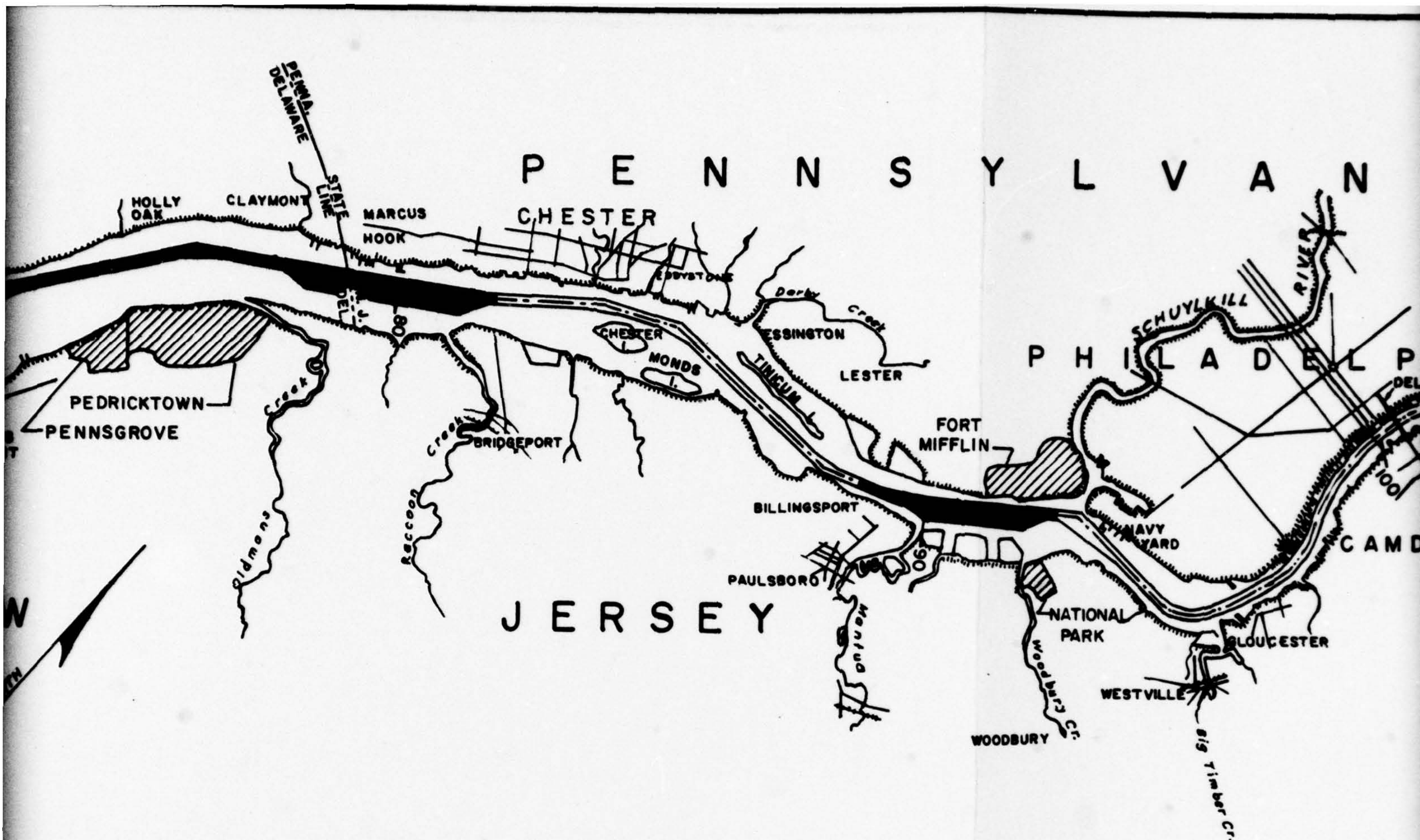
III. CONCLUSIONS

The system of training dikes for the Delaware Estuary as tested in the hydraulic model at the Waterways Experiment Station consisted of a series of long dikes generally parallel to the river channels and tied to the shore at the upper end. Plan 11 differs from Plan 7 in that the up-river tie-backs to shore were lowered to mean low water to allow a more uniform and greater flow to pass a given section. The extreme length of dikes in the system would cost an enormous amount of money and a very significant benefit must result if such construction were to be seriously considered for accomplishment. The results show a shifting of the intensive shoaling areas, but not always in a downstream direction. It can be concluded that, even though some downstream shifting is evident, desirable objectives were not achieved since the shoaling would be spread along several reaches of the river from Tinicum to Liston Ranges. The goal of getting much of the shoaling to occur much closer to the Artificial Island areas could not be realized.

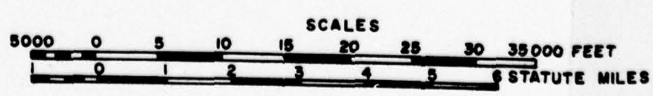
Since even this extensive system of dikes did not show the desired results, an ultimate shoreline pattern was not developed that could serve as a goal toward which any changes should be directed. Two of the training dikes that were located adjacent to and partially encroaching on the Mantua and Marcus Hook Anchorages did effect a considerable reduction in shoaling of the anchorage area due to decrease in flow area. Therefore, if these anchorages could be eliminated or reduced in size the dikes adjacent to these areas could be incorporated into such a plan.


DELAWARE
NEWPORT
WILMINGTON
Christina River
NEW CASTLE
CARNEYS POINT
ST. GEORGES
CHESAPEAKE & DELAWARE CANAL
DELAWARE CITY
PEA PATCH ISLAND
60
PENNSVILLE
PENNS NECK
KILLCOHOOK
NEW
NORTH
REEDY PT.
Salem River
PORT PENN
REEDY I.
SALEM
REP
GOV
DEL N.J.
50
Alloway Creek
ARTIFICIAL ISLAND
DIVIDING LINE
Liston Pt.
DELAWARE RIVER
DELAWARE BAY
Delaware Pt.
Smyrna R.

1

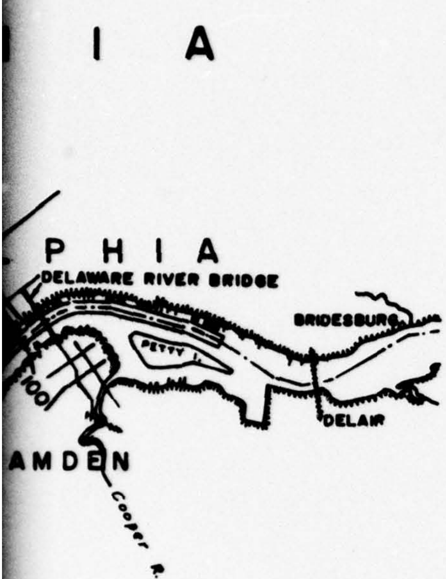


LEGEND	NAME OF MAJOR SHOAL	ANNUAL SHOALING RATE
REPETITIVE SHOAL AREAS	NEW CASTLE	1 800 000 C.Y.
GOVT. OWNED DISPOSAL AREAS	MARCUS HOOK	4 000 000 C.Y.
	MIFFLIN	1 500 000 C.Y.



1

2

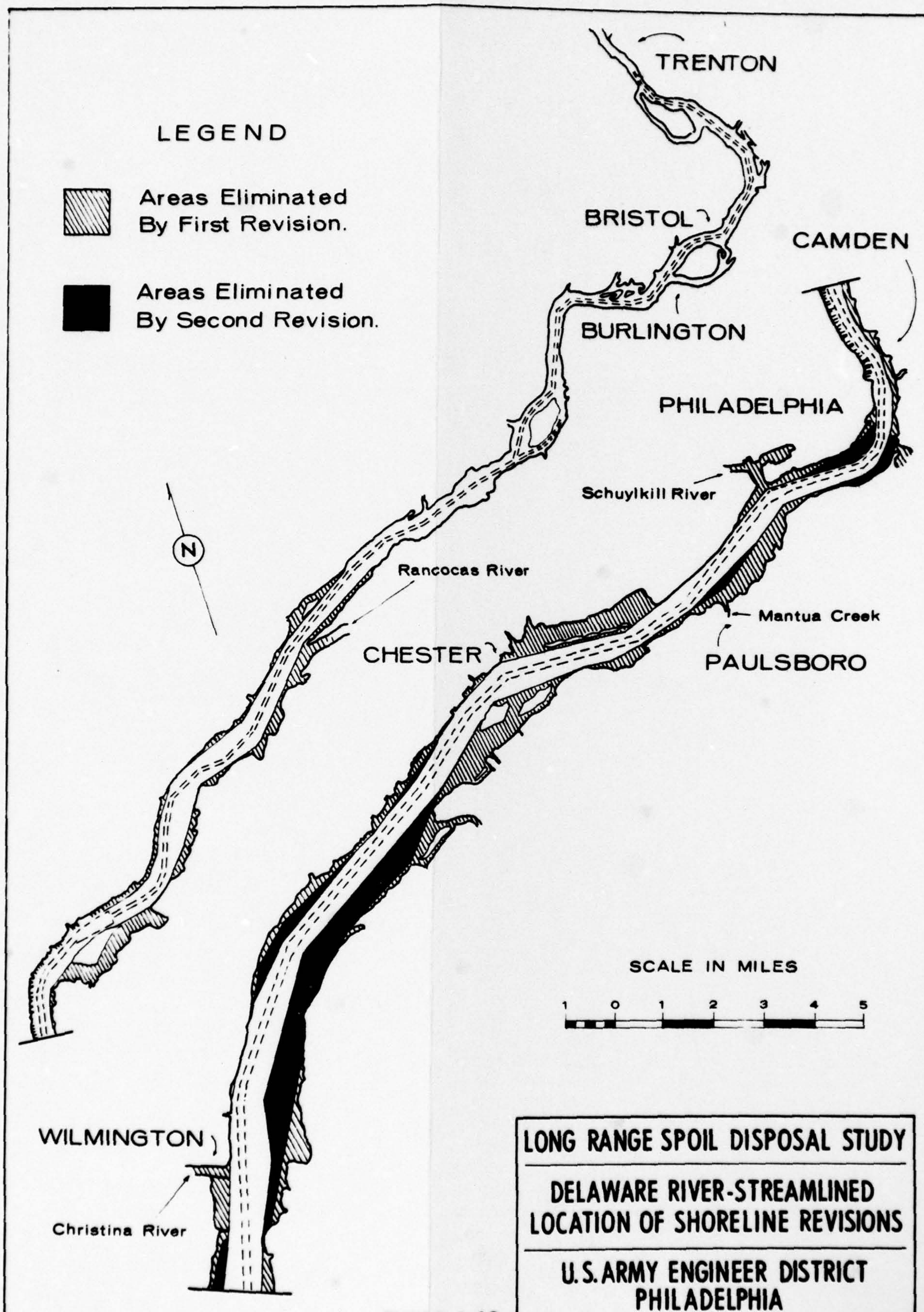


LONG RANGE SPOIL DISPOSAL STUDY

DELAWARE RIVER
MAJOR SHOALS

U. S. ARMY ENGINEER DISTRICT
PHILADELPHIA

PLATE 1



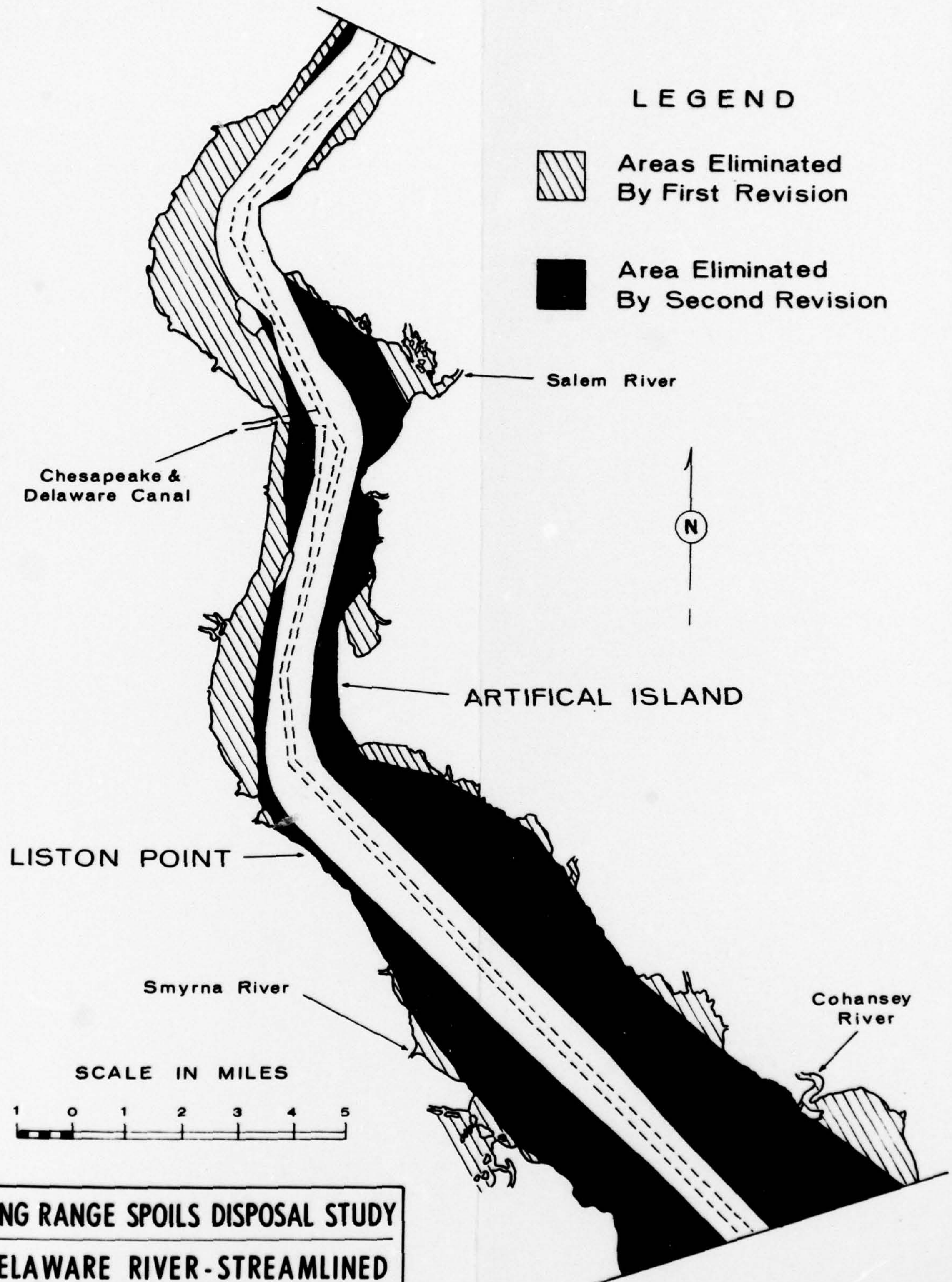
LONG RANGE SPOIL DISPOSAL STUDY

DELAWARE RIVER-STREAMLINED
LOCATION OF SHORELINE REVISIONS

U.S. ARMY ENGINEER DISTRICT
PHILADELPHIA

SHEET 1 of 3

PLATE 2-A

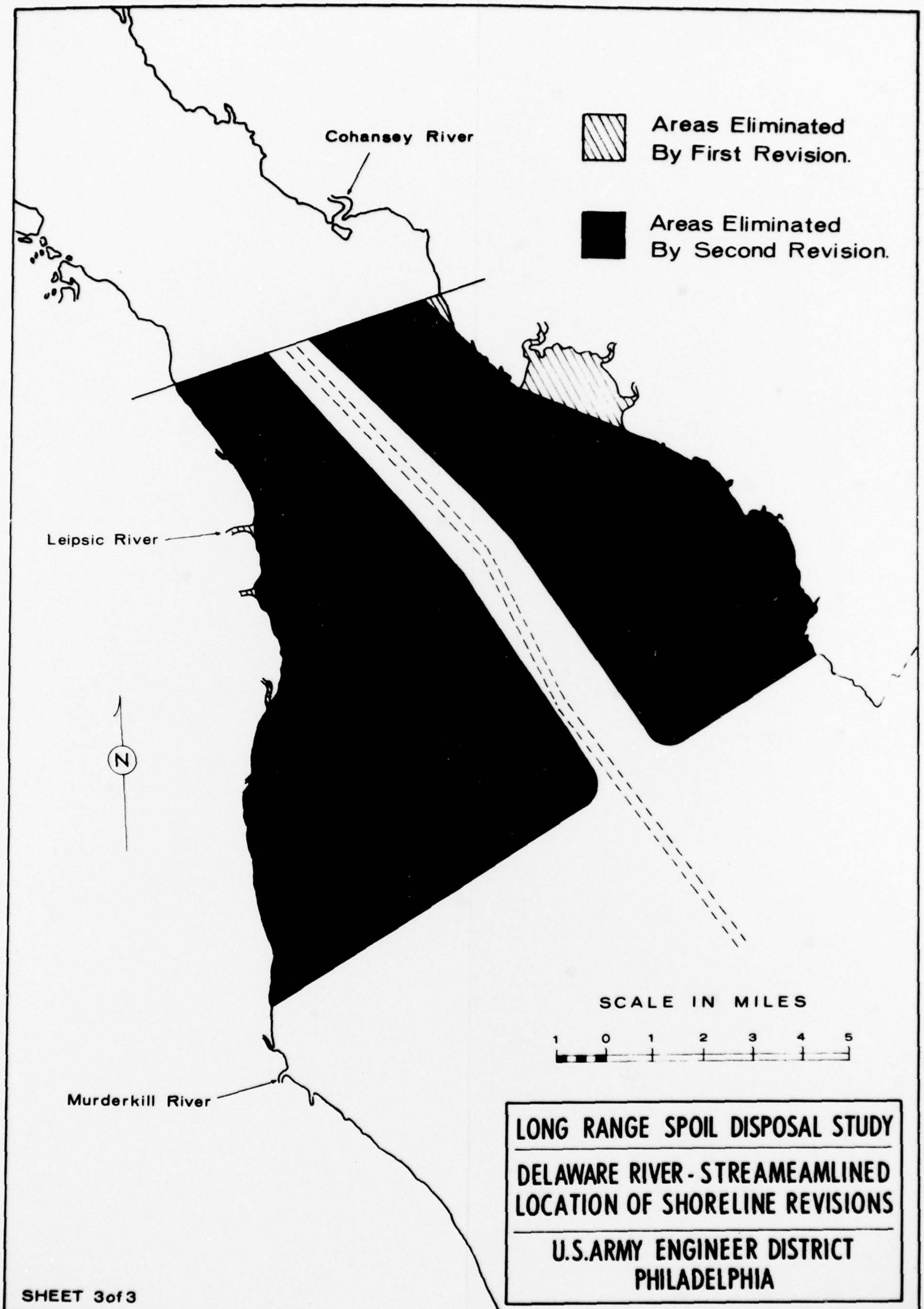


LONG RANGE SPOILS DISPOSAL STUDY

DELAWARE RIVER - STREAMLINED LOCATION OF SHORELINE REVISIONS

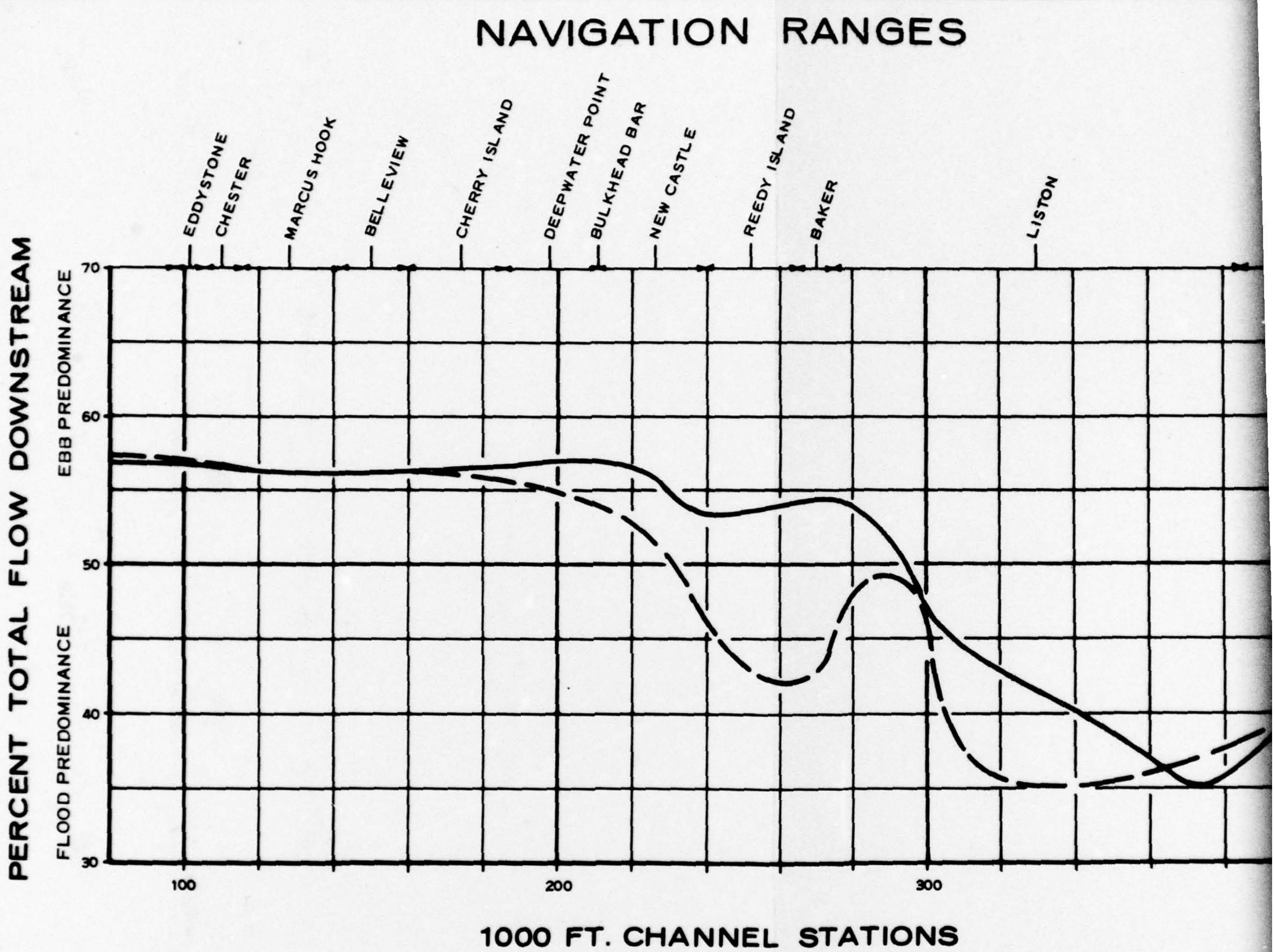
U.S. ARMY ENGINEER DISTRICT PHILADELPHIA

SHEET 2 of 3



Areas Eliminated
By First Revision.
Areas Eliminated
By Second Revision.
Cohansey River
Leipsic River
Murderkill River
N
SCALE IN MILES
1 0 1 2 3 4 5
LONG RANGE SPOIL DISPOSAL STUDY
DELAWARE RIVER - STREAMEAMLINED
LOCATION OF SHORELINE REVISIONS
U.S.ARMY ENGINEER DISTRICT
PHILADELPHIA
SHEET 3of3

PLATE 2-C



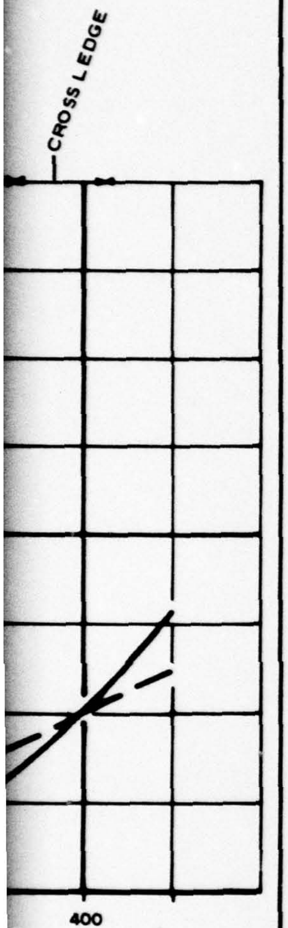
BASE TEST

PLAN 11 DIKES

LONG RANGE SPOIL DISP

DELAWARE RIVER
VELOCITY DA
BOTTOM FLOW PRED

U. S. ARMY ENGINEER
PHILADELPHIA



SPOSAL STUDY
ER MODEL
ATA
DOMINANCE
R DISTRICT
IA

PLATE 3

2

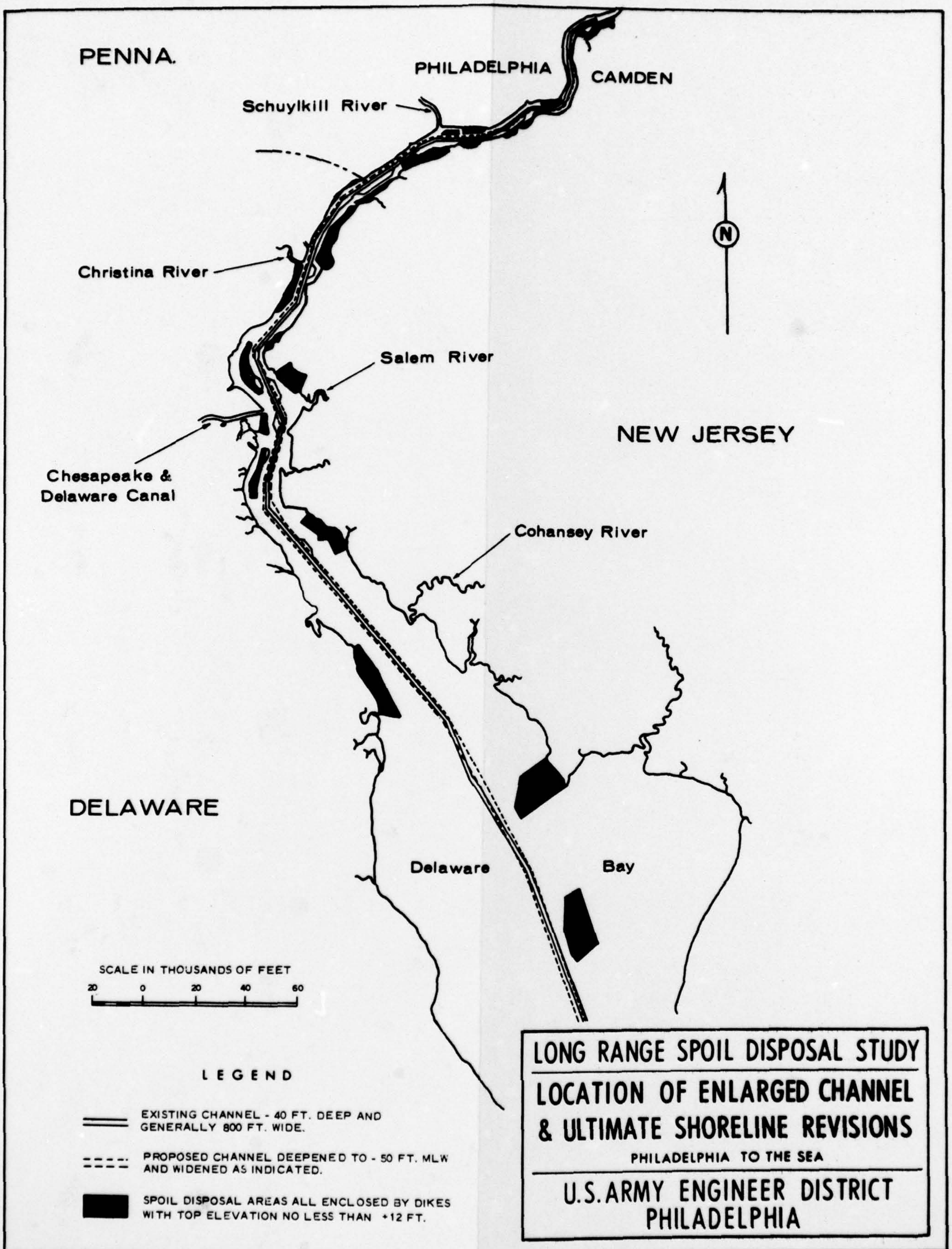
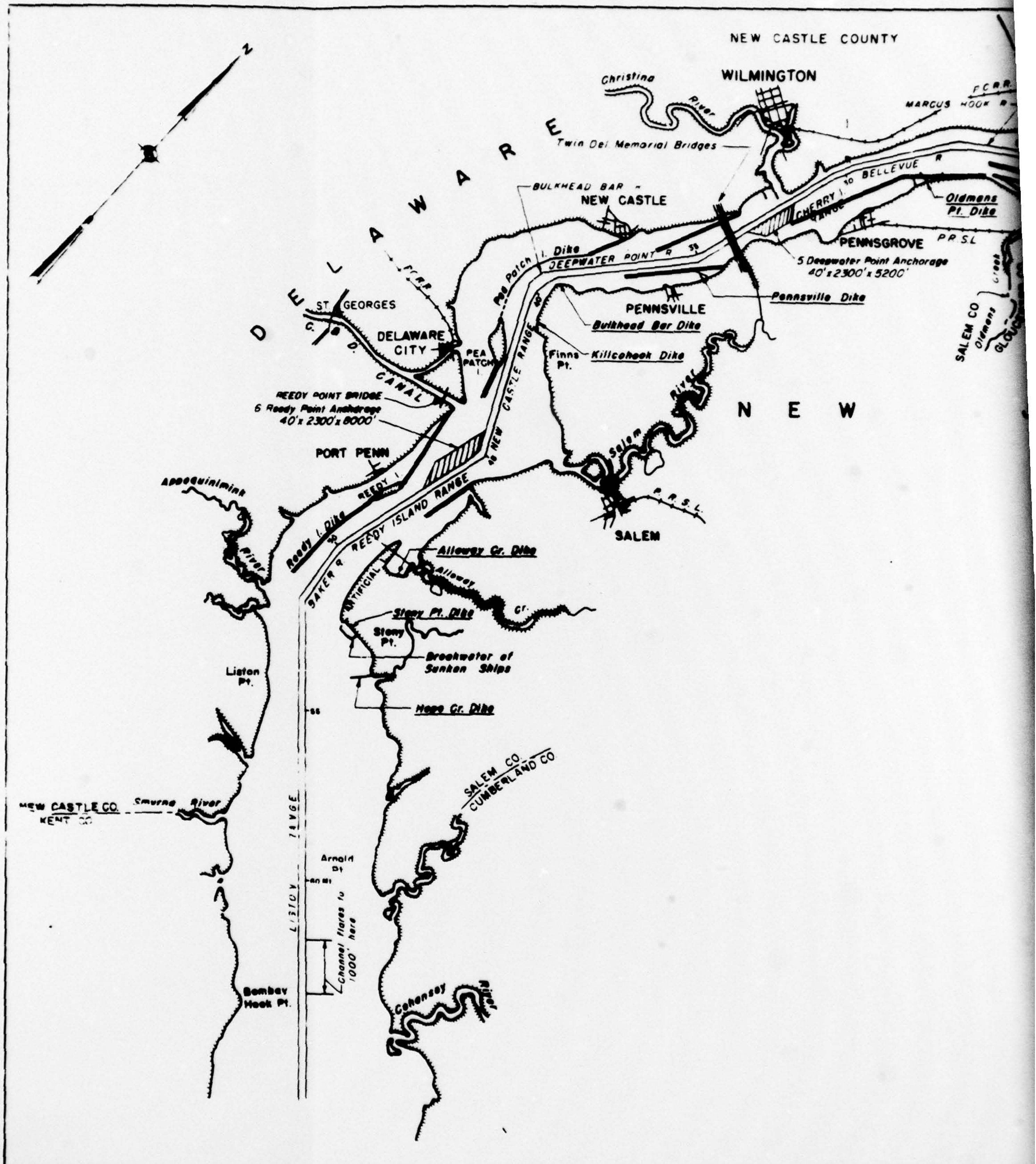
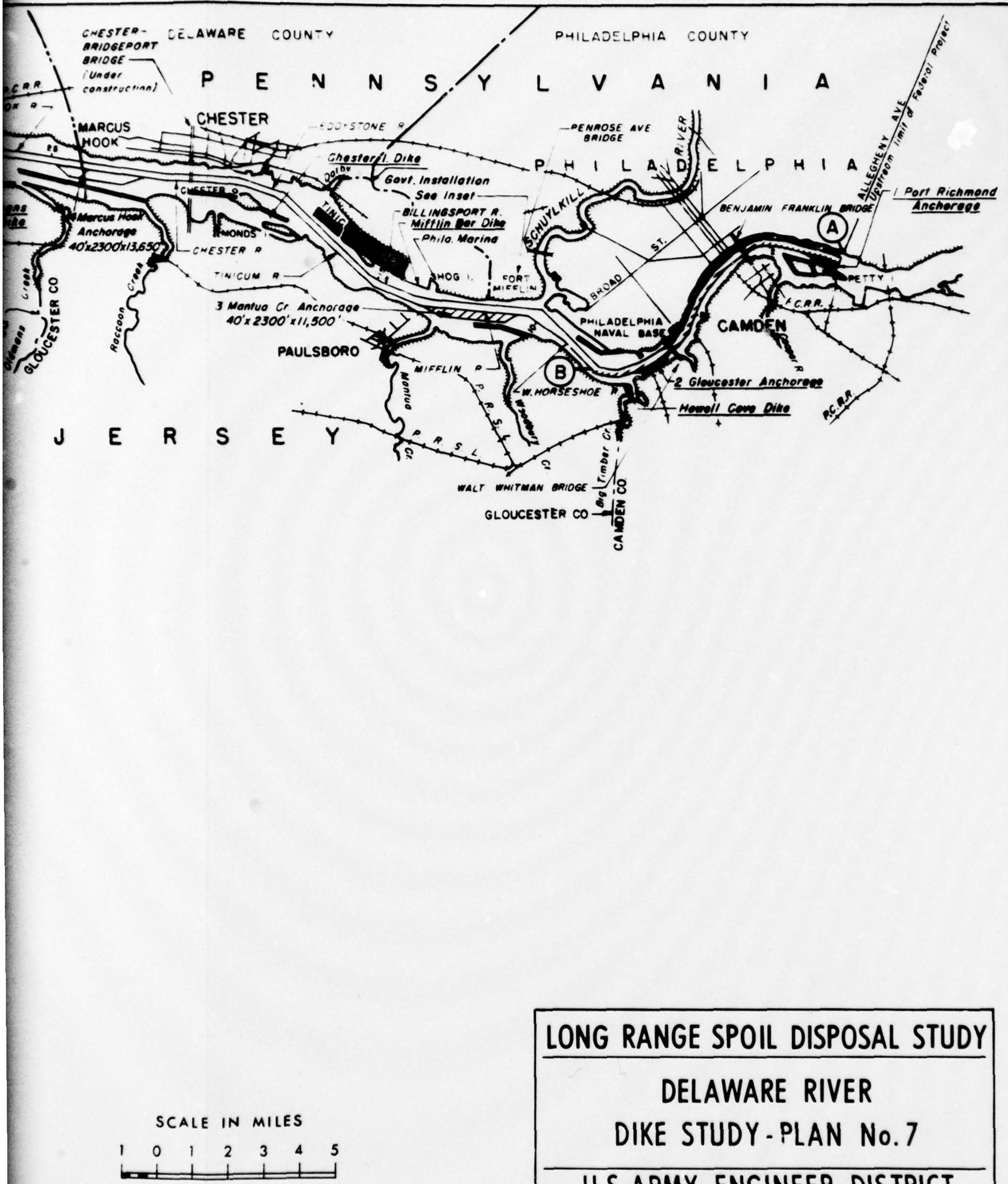

PENNA.
PHILADELPHIA
CAMDEN
Schuylkill River
Christina River
Salem River
NEW JERSEY
Chesapeake &
Delaware Canal
Cohansey River
N
DELAWARE
Delaware
Bay
SCALE IN THOUSANDS OF FEET
20 0 20 40 60
LEGEND
EXISTING CHANNEL - 40 FT. DEEP AND GENERALLY 800 FT. WIDE.
PROPOSED CHANNEL DEEPENED TO - 50 FT. MLW AND WIDENED AS INDICATED.
SPOIL DISPOSAL AREAS ALL ENCLOSED BY DIKES WITH TOP ELEVATION NO LESS THAN +12 FT.
LONG RANGE SPOIL DISPOSAL STUDY
LOCATION OF ENLARGED CHANNEL & ULTIMATE SHORELINE REVISIONS
PHILADELPHIA TO THE SEA
U.S. ARMY ENGINEER DISTRICT
PHILADELPHIA

PLATE 4


N
NEW CASTLE COUNTY
WILMINGTON
Christina
River
MARCUS HOOK R
Twin Del Memorial Bridges
DELAWARE
BULKHEAD BAR
NEW CASTLE
CHERRY I.
BELLEVUE R
Oldmans Pt. Dike
PENNSGROVE
P.R.S.L.
5 Deepwater Point Anchorage 40'x2300'x5200'
Pea Patch I. Dike
DEEPWATER POINT R
ST. GEORGES
C. & D. CANAL
DELAWARE CITY
PEA PATCH I.
PENNSVILLE
Pennsville Dike
Bulkhead Bar Dike
Killcohook Dike
Finns Pt.
NEW CASTLE RANGE
SALEM CO.
Oldmans
REEDY POINT BRIDGE
6 Reedy Point Anchorage 40'x2300'x8000'
NEW
PORT PENN
Salem River
Appoquinimink River
Reedy I. Dike
REEDY I.
REEDY ISLAND RANGE
BAKER R
SALEM
P.R.S.L.
Alloway Cr. Dike
Alloway Cr.
ARTIFICIAL I.
Stony Pt. Dike
Stony Pt.
Breakwater of Sunken Ships
Liston Pt.
Hope Cr. Dike
NEW CASTLE CO.
KENT CO.
Smyrna River
SALEM CO.
CUMBERLAND CO.
LISTON RANGE
Arnold Pt.
Channel flares to 1000' here
Bombay Hook Pt.
Cohansey River



LONG RANGE SPOIL DISPOSAL STUDY

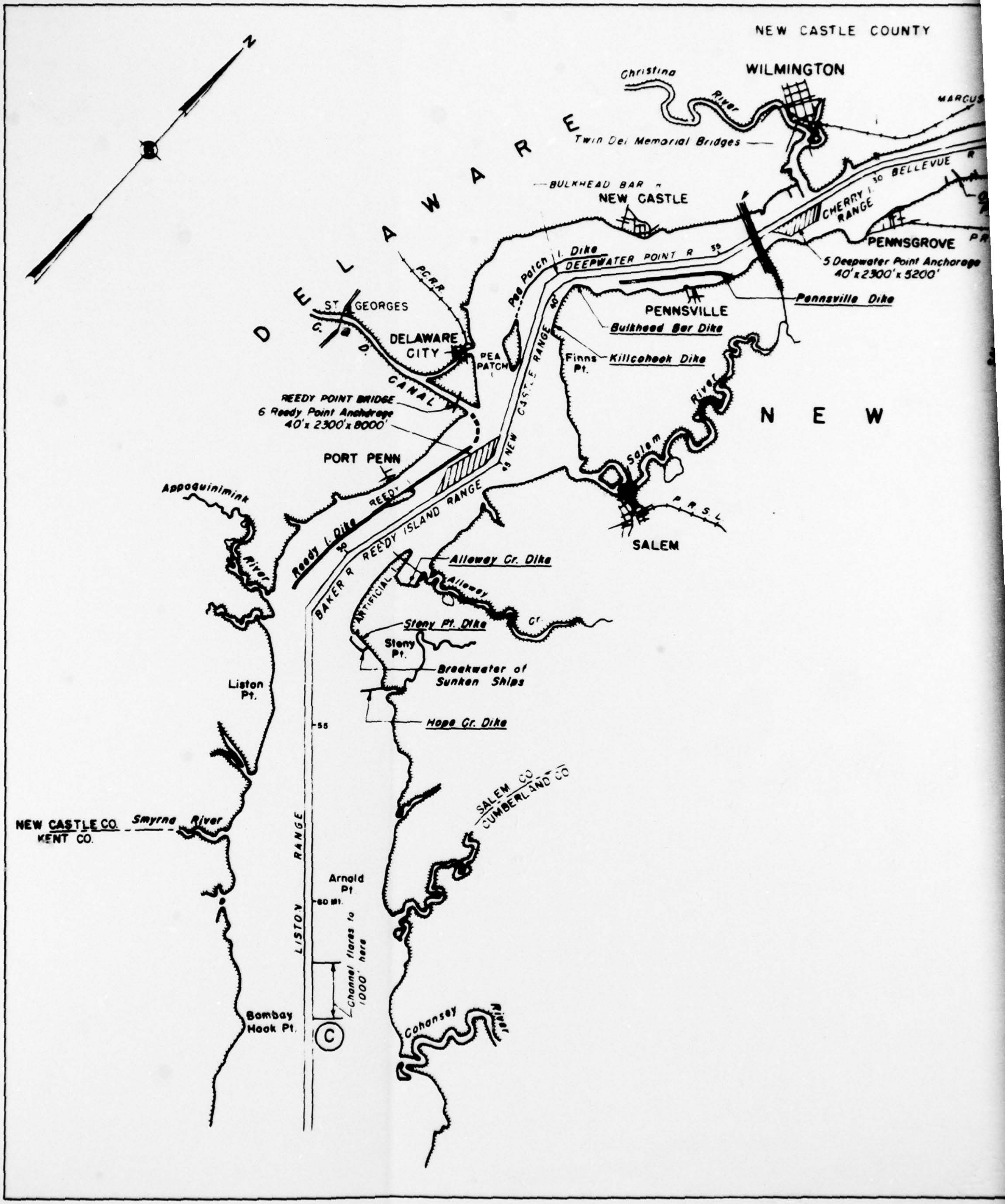
DELAWARE RIVER

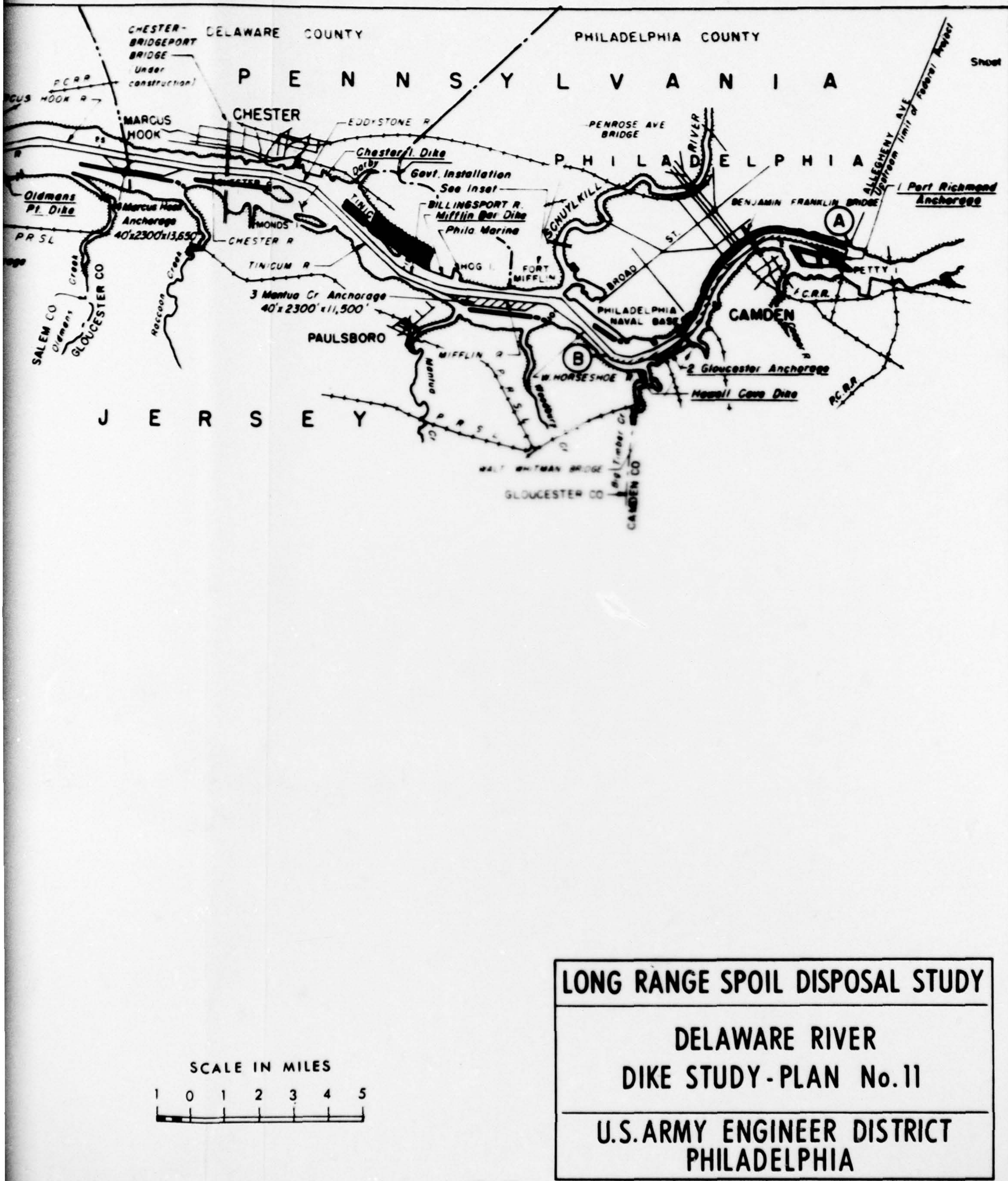
DIKE STUDY - PLAN No. 7

U.S. ARMY ENGINEER DISTRICT
PHILADELPHIA

PLATE 5

2


NEW CASTLE COUNTY
WILMINGTON
Christina River
Twin Del Memorial Bridges
BULKHEAD BAR
NEW CASTLE
DELAWARE
CHERRY I. RANGE
BELLEVUE R
PENNSGROVE
5 Deepwater Point Anchorage
40' x 2300' x 5200'
Pennsville Dike
Pea Patch I. Dike
DEEPWATER POINT R
PENNSVILLE
Bulkhead Bar Dike
ST. GEORGES
P.C.R.R.
C. & D. CANAL
DELAWARE CITY
PEA PATCH I.
Finns Pt.
Killcohook Dike
NEW CASTLE RANGE
NEW
REEDY POINT BRIDGE
6 Reedy Point Anchorage
40' x 2300' x 8000'
PORT PENN
Salem River
Appoquinimink River
Reedy I. Dike
REEDY ISLAND RANGE
BAKER R
SALEM
P.R.S.L.
Alloway Cr. Dike
Alloway Cr.
ARTIFICIAL I.
Stony Pt. Dike
Stony Pt.
Breakwater of Sunken Ships
Liston Pt.
Hope Cr. Dike
SALEM CO
CUMBERLAND CO
NEW CASTLE CO.
KENT CO.
Smyrna River
LISTON RANGE
Arnold Pt.
Channel flares to 1000' here
Bombay Hook Pt.
Cohansey River



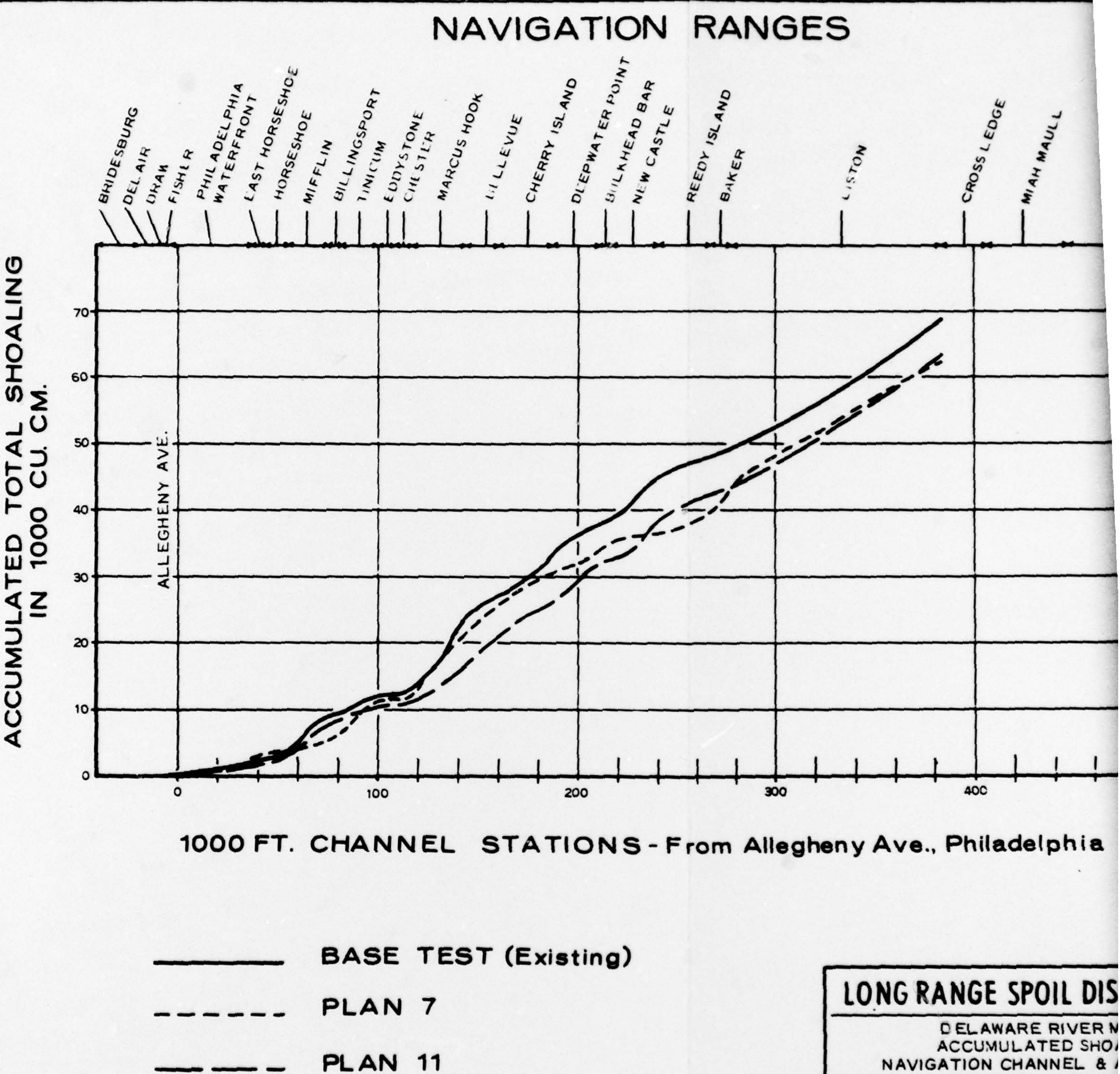
LONG RANGE SPOIL DISPOSAL STUDY

DELAWARE RIVER
DIKE STUDY - PLAN No. 11

U.S. ARMY ENGINEER DISTRICT
PHILADELPHIA

PLATE 6

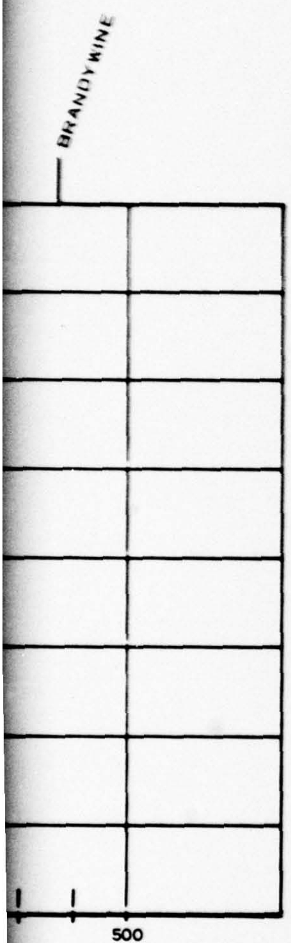
2



LONG RANGE SPOIL DIS

DELAWARE RIVER M
ACCUMULATED SHOA
NAVIGATION CHANNEL & A
EXISTING VS. PLAN
DELAIR TO LISTON RA

U. S. ARMY ENGINEE
PHILADELPH



a

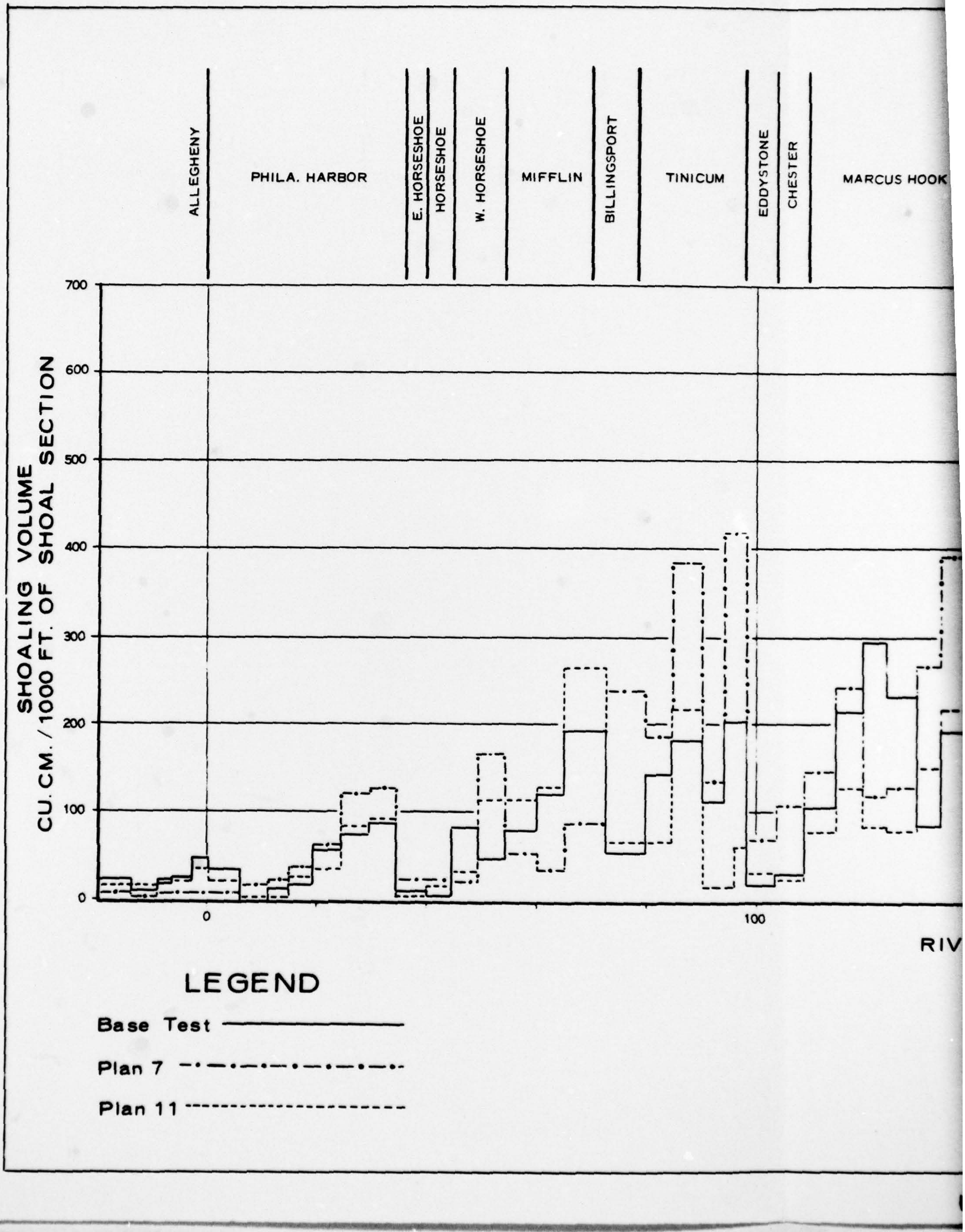
ISPOSAL STUDY

R MODEL
HOALING
& ANCHORAGES
ANS 7 & 8
RANGES INCL.

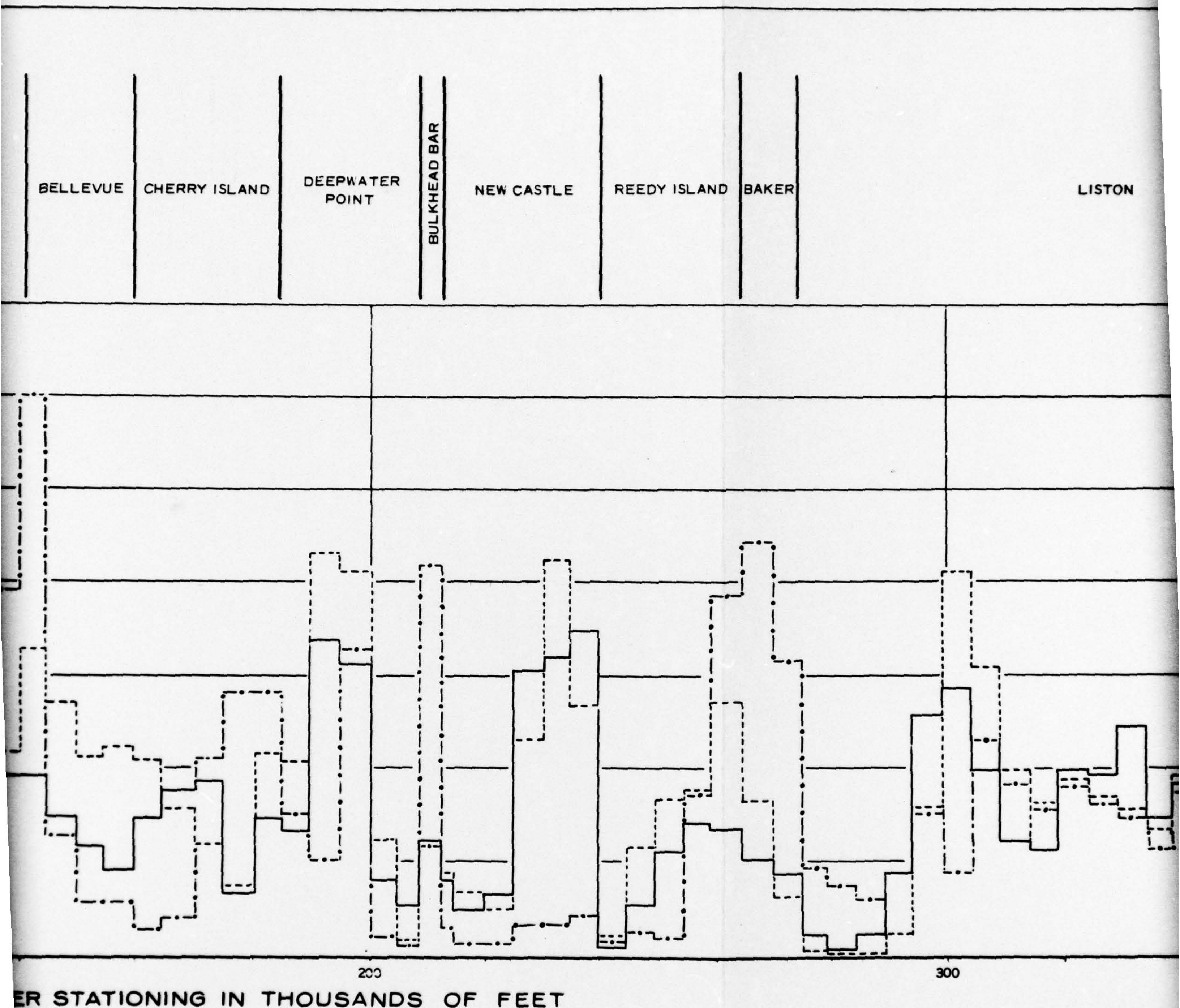
ER DISTRICT
PHIA

PLATE 7

2

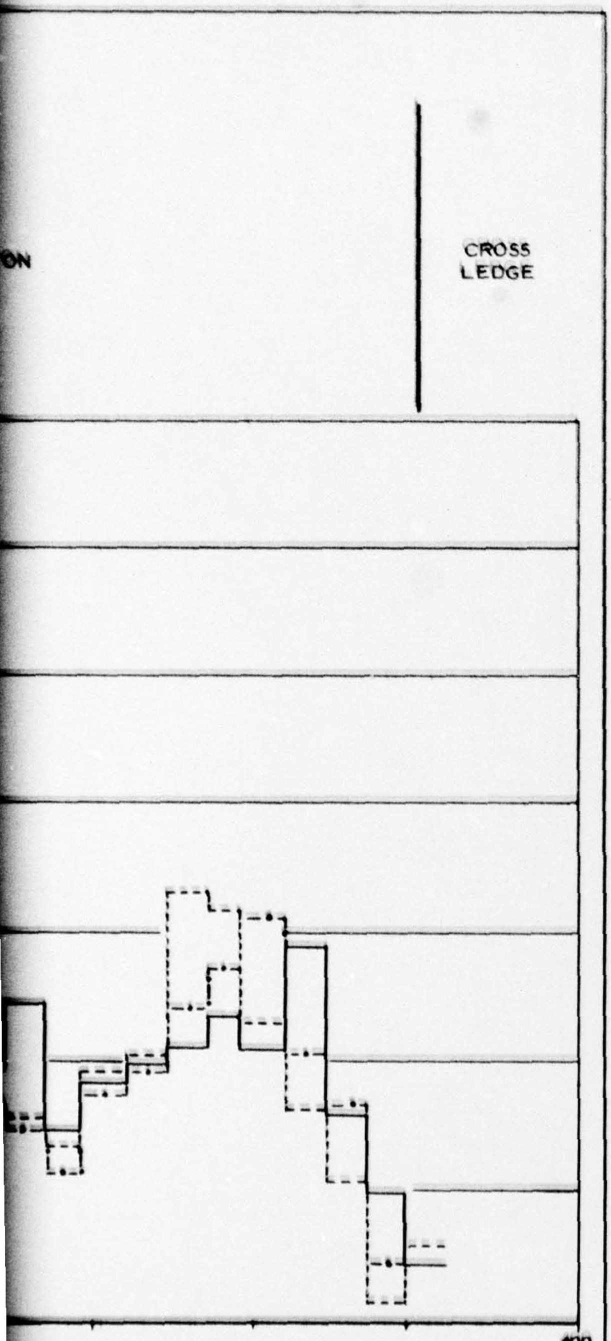


ALLEGHENY
PHILA. HARBOR
E. HORSESHOE
HORSESHOE
W. HORSESHOE
MIFFLIN
BILLINGSPORT
TINICUM
EDDYSTONE
CHESTER
MARCUS HOOK
SHOALING VOLUME
CU.CM. / 1000 FT. OF SHOAL SECTION
700
600
500
400
300
200
100
0
0
100
RIV
LEGEND
Base Test
Plan 7
Plan 11


BELLEVUE
CHERRY ISLAND
DEEPWATER POINT
BULKHEAD BAR
NEW CASTLE
REEDY ISLAND
BAKER
LISTON
200
300
ER STATIONING IN THOUSANDS OF FEET

LON
T
U.

2 .



LONG RANGE SPOIL DISPOSAL STUDY

DELAWARE RIVER MODEL
TESTS OF TRAINING DIKES
SHOALING RATES

U. S. ARMY ENGINEER DISTRICT
PHILADELPHIA

PLATE 8

2 3